C5. New Data/Scatt.

Assimilation of SeaWinds Scatterometer Data in the GEOS Data Assimilation System

1. Introduction

Accurate observations of surface wind velocity over the oceans are required for a wide range of meteorological and oceanographic applications. Surface winds are needed to drive ocean models and surface wave models, to calculate surface fluxes of heat, moisture and momentum, and to construct surface climatologies. In addition, surface wind data are essential for nowcasting weather and wave conditions at sea, and to provide initial conditions and verification data for numerical weather prediction (NWP) models.

Prior to the launch of satellites capable of determining ocean surface winds from space, observations of surface wind velocity were obtained primarily from ships and buoys. Such "conventional" observations continue to be important components of the global observing system despite their limitations in coverage and accuracy. Reports of surface winds from ships cover only very limited regions of the world's oceans, occur at irregular intervals of time and space, and are at times of poor accuracy. Buoys, while of higher accuracy, have even sparser coverage. As a result, analyses based only on these *in situ* observations can misrepresent surface wind over large regions and are generally not adequate.

Scatterometer data from satellites offer an effective way to fill data voids as well as to provide data at a higher resolution than conventional data. There has been a steady evolution in the capabilities of scatterometer instruments over the past decade. The European Remote Sensing (ERS) scatterometer design provides coverage over 90% of the ocean within 96 hours. The NASA Scatterometer (NSCAT) design provided coverage over 90% of the ocean within 48 hours. The new SeaWinds design on QuikSCAT has the potential to provide over 90% coverage within 24 hours.

2. SeaWinds Description

Scatterometers differ from SSM/I in their strategy for obtaining ocean surface wind information. The passive sensing of ocean winds employs a "double inference" strategy: surface winds create a "sea-state" whose steepness will correspond in some way to the wind speed; the passive retrievals basically seek to detect these features through signals received from radiation emitted in different polarizations (horizontal and vertical) from the ocean surface. Scatterometers operate on the principle of measuring the power reflected from small, on the order of a few centimeters wavelength, capillary waves on the ocean surface that are created by the wind blowing across the water's surface. The wavelength of the radars used are comparable to those of the capillary waves, which makes the Bragg scattering process most efficient. The reflected power (referred to as "backscatter") for a given wind speed should vary from larger values for winds blowing in the direction of a radar antenna to smaller values for winds blowing perpendicular to an antenna's orientation; thus measurements from different antenna angles can yield information about wind direction as well as speed.

A key element in the process of extracting surface winds from radar backscatter measurements is the *geophysical model function*. Currently, these model functions are empirically derived relations and they generally have the form:

$$\sigma^0 = f\left(S, \chi, \theta, p\right),$$

where σ^0 is the backscatter measured by a given antenna, S = wind speed, χ = relative angle of the surface wind vector to the surface projection of the radar beam from that antenna, θ = the incidence angle of the radar beam to the ocean surface and p = the polarization (horizontal or vertical) of the radar beam. Multiple measurements of σ^0 from different looking angles in space thus could provide enough information for retrieving a surface wind vector by inverting the model function.

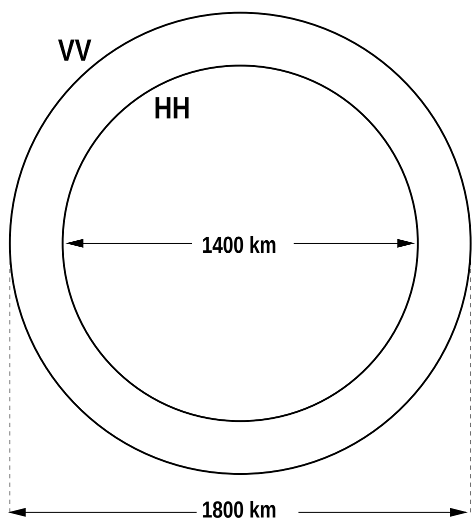

Figure 1 : Single sweep of SeaWinds radar, showing the traces for the two fixed incidence angles. The outer beam is vertically polarized, the inner beam is horizontally polarized. The beam "footprint" is roughly 30 by 40 km. The dish antenna makes one full sweep in 3 seconds (during which the along-track displacement is 20 km).

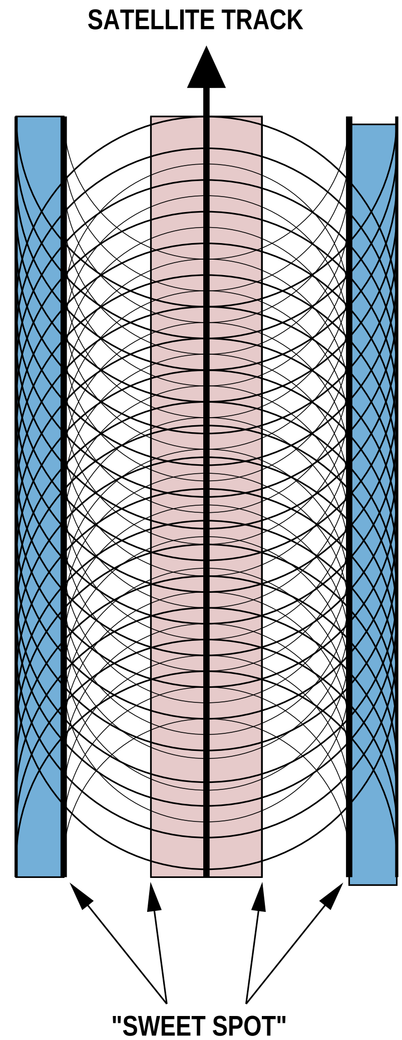

Figure 2 : Schematic of SeaWinds swath. Best opportunities for wind retrievals should occur in the two 450 km wide "sweet spots" (unshaded areas) on either side of the satellite track. Wind retrievals are performed where there are multiple "hits" or intersections of scans.

A major design constraint for NSCAT was that all six antennas have an unobstructed view of the ocean surface. This constraint was met with some ingenuity on ADEOS-1, but it would have limited the availability of future platforms for this instrument. This and other considerations resulted in a radical redesign of the scatterometer: SeaWinds. This instrument replaces the fixed fan-beam antennas with a single 1 m rotating dish, which illuminates two spots on the ocean surface. In addition to being more "platform friendly" in terms of design constraints, there are other benefits to this configuration, the chief one being that each of the spots have an approximately constant incident angle. This should lead to simpler geophysical model functions, and thus to more robust wind retrievals.

As a result of its dual-scanning approach, SeaWinds sweeps out a swath approximately 1800 km wide (900 km on either side of the satellite track), Figure 1 shows a rough schematic. Within this track are three subregions (Figure 2) each of which having a different sampling nature:

- $\pm$ 250 km from nadir track: 4 looks, insufficient azimuthal angle diversity for adequate point-wise wind retrieval;
- 250-700 km from nadir: 3-4 looks, performance "sweet spot" where number and diversity of azimuth looks should yield good retrieval performance (90% coverage in 2 days);
- 700-900 km from nadir: 1-2 looks, vertical polarization only, insufficient azimuthal angle diversity for adequate point-wise wind retrieval.

The processed Quikscat SeaWinds data will have a 25 km resolution. One of the major issues with the geophysical validation will be the investigation of the quality of the processed wind vector product in the various subregions; of especial interest is the nature and quality of the retrieved winds in the extended regions outside of the optimal sweet spot zone. Successful retrievals of wind data in the extended zones could as much as double the coverage achieved by the SeaWinds instrument.

3. DAO Activities

The DAO maintains an active scatterometer research program and is preparing for the operational assimilation of SeaWinds data from Quikscat following formal release of these data. Previous research performed by DAO scientists resulted in the first methodology for assimilating ambiguous scatterometer winds and produced the first global surface wind and air sea flux data set using Seasat scatterometer observations. DAO scientists served on the Satellite Surface Stress (S-cubed) Committee that planned the NASA Scatterometer (NSCAT). Currently DAO scientists serve on the ERS, NSCAT, SeaWinds, and JASON-1 Science Teams and Chair the U. S. WOCE Advisory Group for Model-Based Air-Sea Fluxes.

One of the major DAO activities in scatterometer research is geophysical validation in support of the instrument teams. The DAO performed a detailed validation of NSCAT (Atlas *et al.*, 1999). Results from this evaluation indicate that the NSCAT data is extraordinarily useful. Collocation comparisons showed the NSCAT winds to be of higher accuracy than the operational ERS-2 wind data, and consistent positive impacts were found with this data in the GEOS 1, GEOS 2 and NCEP data assimilation systems. Overall, the DAO determined that the geophysical validation for NSCAT wind data demonstrated the excellent quality and high degree of utility of these data for both scientific and operational uses.

The DAO is currently performing a similar evaluation for Quickscat. This includes (1) collocations of SeaWinds scatterometer data with ships, buoys, low level aircraft and cloud track winds, SSMI and ERS winds and operational model analyses, (2) synoptic evaluation of the scatterometer winds by experiences meteorologists, and (3) limited data assimilation experiments using both the

GEOS DAS and the NCEP operational DAS. (This is performed as a collaborative project between the DAO and NCEP.) Key aspects of the assimilation of scatterometer data in GEOS are multivariate sea level pressure-surface wind analysis, consistent sectional extension of the single level surface wind observations, and asynoptic treatment of the scatterometer data. All of these effects have been known to be important in obtaining the maximum impact of scatterometer data. (Atlas and Hoffman, 2000)

The geophysical validation of the initial data from Quikscat has indicated potential for SeaWinds data to improve atmospheric analyses, air sea fluxes, and forecasts, but has also shown significant problems with the initial data sets that are currently limiting their application. Figure 3(a,b) shows the impact of the initial Quikscat data on GEOS-2 forecasts for sea level pressures and for 500 hPa heights, for 11 cases during the Summer of 1999. The impact so far is small but positive in the Northern Hemisphere but somewhat larger in the Southern Hemisphere.

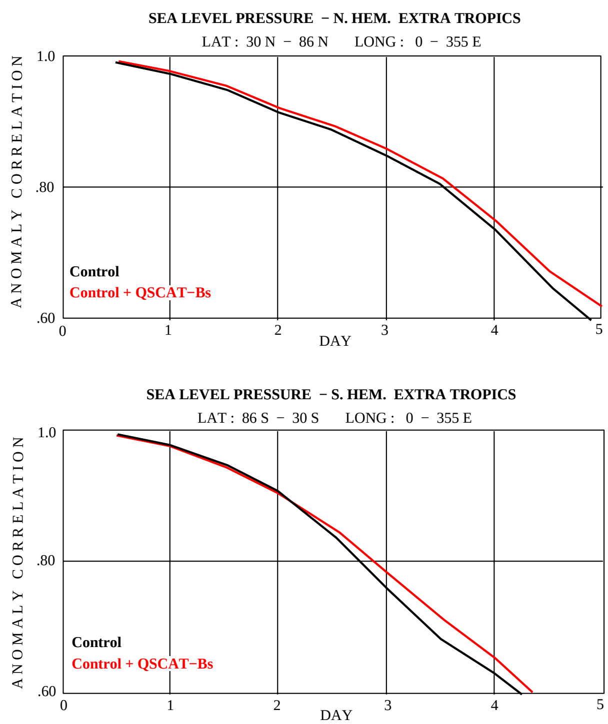

Figure 3a : Sea level pressure anomaly correlations.

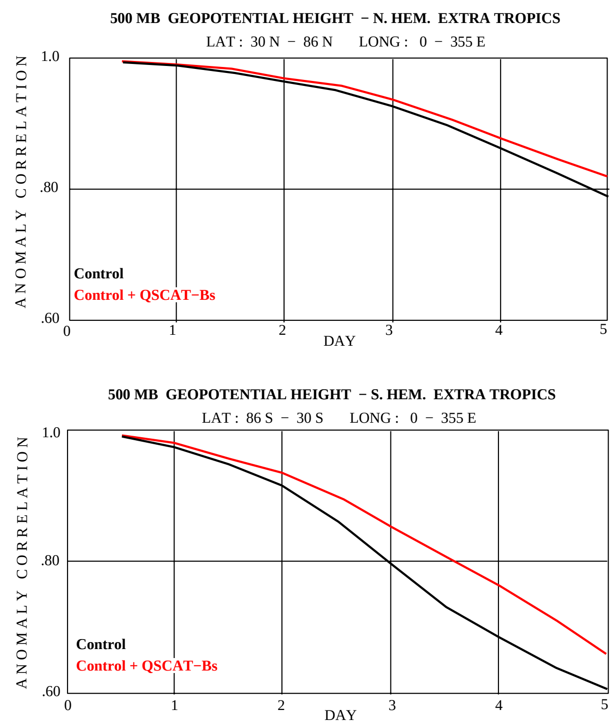

Figure 3b : 500 hPa height anomaly correlations.

4. References

Atlas, R., S.C. Bloom, R.N. Hoffman, E. Brin, J. Ardizzone, J. Terry, D. Bungato and J.C. Jusem, 1999: Geophysical validation of NSCAT winds using atmospheric data and analyses. *J. Geophys. Res.*, **104**(C5), 11405-11424.

Atlas, R. and R.N. Hoffman, 2000: The use of satellite surface wind data to improve weather analysis and forecasting. To appear in **Satellites, Oceanography and Society**.